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Laparoscopic Nonanatomic Hepatic Resection Employing the LigaSure Device

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ABSTRACT

Background: Advancements in technology have allowed laparoscopic surgery to expand into advanced procedures such as liver resection; however, the value and safety of laparoscopic liver surgery is still a topic for debate. This study was designed to evaluate the feasibility and outcome of laparoscopic nonanatomic hepatectomy using the LigaSure device in a swine model.

Methods: Nonanatomic hepatic lobe resection was performed in 3 groups comparing the open finger-fracture method, the open method with the LigaSure device, and the laparoscopic method with the LigaSure device. The cut surfaces of the liver were evaluated for bleeding and biliary leakage at the time of the operation. The animals were inspected 48 hours later for hemorrhage and evaluated with cholescintigraphy (hepatobiliary iminodiacetic acid [HIDA] scan) for biliary leakage, in addition to histological evaluation of liver specimens.

Results: No hemorrhage or biliary leakage was noted in the groups where the LigaSure device was used, whereas 1 animal from the open finger-fracture method sustained a bile leak observed on HIDA scan. The operative blood loss was considerably less in the groups where the LigaSure device was used, and the shortest operative time was observed in the laparoscopic group.

Conclusions: The LigaSure device can be safely and effectively used to perform a laparoscopic nonanatomic hepatectomy.

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INTRODUCTION

Laparoscopic surgery has enjoyed increasing success since its modest beginning in 1983 and has become the standard of care for cholecystectomy. Evaluation and application of new technologies has allowed for the rapid advancement of laparoscopic surgical techniques.[1–4] What remains ill-defined is the application and safety of laparoscopic surgery to complex solid-organ procedures such as liver resection.[5–7] The difficulties in approaching laparoscopic liver surgery require continued improvements in technology, such as video imaging, electrosurgical instruments, laparoscopic duplex ultrasound, and greater success with bloodless surgery.[8] One possible application of advancements in laparoscopic liver surgery is the performance of partial nonanatomic hepatectomy. Using open surgical techniques, partial nonanatomic hepatectomy has gained acceptance as a procedure that may be used to treat patients with hepatocellular carcinoma, as well as other diagnoses.[9,10] Nonanatomic liver resection is technically demanding due to hepatic anatomic variability and can be associated with considerable morbidity.[11] Inherent problems include bleeding and biliary leakage from the cut surface of the liver.[12]

This study evaluated a new technique for liver resection using the LigaSure electrosurgical vessel-sealing device (Valleylab-Tyco Healthcare, Boulder, CO). The laparoscopic Atlas version of the device both seals and divides blood vessels. It does so by combining energy control with physical compression, including a brief cool down that produces a distinctive, translucent seal of partially denatured protein; thereby, fusing the collagen in the vessel walls and occluding the lumen entirely.

These seals have bursting strengths comparable to those of ligatures and, unlike clips, resist dislodgment because they are intrinsic to the vessel wall structure. Thermal spread is minimal and the autologous seals formed by the LigaSure device can withstand 3x systolic pressure. The LigaSure device may be used for sealing vessels up to 7 mm in diameter.[13] It is used routinely at our institution for laparoscopic living-donor nephrectomy. The effectiveness of this device for liver resection is not known, but we hypothesize that it has excellent potential for use in laparoscopic nonanatomic liver resection. This series is our initial experience with the LigaSure device in the performance of laparoscopic nonanatomic resections of the liver using a *Sus scrofa* pig model.

METHODS

The animal experiments were performed in accordance with the 1996 National Research Council *Guide for the Care and Use of Laboratory Animals* and applicable federal regulations. Preoperatively, the animals were fasted 12 hours and medicated with hydromorphone (0.1 mg/kg), acepromazine (0.1 mg/kg), and glycopyrrolate (0.01 mg/kg intramuscularly). Anesthesia was induced with tiletamine/zolazepam (Telazol) (6 mg/kg intramuscularly). The animals were then intubated and given xylazine (2 mg/kg intravenously), and anesthesia was maintained using isoflurane (1.5–3%). Monitoring of the anesthetized animals was conducted using pulse oximetry for oxygen saturation, end-tidal carbon dioxide sensors, and cardiac sensors. The 9 domestic swine used in the experiments weighed 29 kg to 36 kg and were divided equally into 3 groups. In all of the experiments, 60% to 80% of the left lobe was removed. Before concluding each operation, all groups of animals (I, II, and III) were visually inspected for bleeding and biliary leakage at the site of resection. In laparoscopic cases, pneumoperitoneum was released for 10 minutes prior to the final visual inspection. In all cases, adequate hemostasis and biliary control was observed, and the abdomen was closed in layers without drains. The animals were weaned from anesthesia and extubated. Postoperative analgesia for Groups I and II consisted of morphine epidural (2 mg) placed between vertebrae L6 and S1 in addition to a transdermal fentanyl patch (75 μg) stapled to the animals' posterior neck. Postoperative analgesia for Group III consisted of buprenorphine (0.01 mg/kg q 12 hours) and a transdermal fentanyl patch (75 μg) stapled to the animals' posterior neck. No antibiotics were given postoperatively. Surgical details of liver resections were as follows:

Group I

The control animals underwent a nonanatomic left hepatic lobectomy through a scalpel incision in the abdominal midline by using the finger-fracture method. Blood vessels and bile ducts were clipped or suture ligated as appropriate and electrocautery (Bovie) was used where indicated.

Group II

The animals in Group II underwent a nonanatomic left hepatic lobectomy through a scalpel incision in the abdominal midline. Division of the liver was accomplished with electrocautery and Metzenbaum scissors. The LigaSure device was used for sealing blood vessels and bile ducts.

Group III

The animals in Group III underwent a laparoscopic, nonanatomic, left hepatic lobectomy with the LigaSure device for dividing the liver parenchyma and sealing and dividing all blood vessels and bile ducts. The pneumoperitoneum was insufflated by Veress needle and maintained at a constant abdominal pressure of 12 mm Hg. Six ports were used during the course of the procedure. A 10-mm trocar placed 2cm below the umbilicus was used for camera placement. The LigaSure device was introduced through a 10-mm trocar.

The laparoscopic Atlas version of the LigaSure was used to divide the parenchyma as well as any vessels or bile ducts in continuity without isolating them first. This was accomplished by opening the jaws of the device and then gently applying pressure to the parenchymal surface. The device was activated by depressing a foot pedal, and increasing pressure applied to the handle, slowly approximating (closing) the jaws. The rate of compression of the parenchyma was guided by the surgeon, who maintained a 1-mm blanched area of parenchyma around the jaws. When the jaws of the device were approximated, indicated by the handle locking, the device was "recycled," ensuring complete sealing of any vessel or duct within the jaws. The excised segment of the liver was placed in an endocatch bag, morselated, and removed through one of the port-site incisions.

Animals from all groups (I, II, and III) were assessed for biliary leakage on postoperative day 2 by cholescintigraphy. Animals were anesthetized with telazol (6 mg/kg intramuscularly) to allow administration of the radiopharmaceutical, Hepatolite (10 millicuries), given via a Jelco 22 gauge needle in the animals' left lateral ear vein. One hour later, a HIDA scan was performed using the ADAC Forte camera, allowing evaluation of hepatocellular function and patency of the hepatobiliary system by tracking the production and flow of radiolabeled bile from the liver through the bile ducts and into the intestine. Following the HIDA scan, all animals underwent a midline abdominal incision for gross inspection of the cut surface of the liver and the surrounding area for any evidence of hemorrhage or biliary leakage. Upon visual inspection, no apparent evidence was present of biliary leakage, resolving hematoma, or abscess formation. Samples of the cut surface were taken for histological examination, and the animals were euthanized with a barbiturate overdose (beuthanasia, 1 mL plus 1 mL/5 kg, intravenously). Sample tissue sections were then H and E stained.

Results were compared using the Mann-Whitney *U* test for statistical significance. $P<0.05$ was regarded as statistically significant.

RESULTS

Intraoperative blood loss and operative times were significantly lower using the LigaSure device and are shown in **Table 1**.

Survival in all 3 groups was 100%. Open resection animals (Groups I and II) were depressed postoperatively, had decreased appetite, and required analgesia. In contrast, laparoscopic animals (Group III) were alert, responsive, and feeding *ad libitum* 1 hour after recovery from anesthesia. Histological examination of excised liver and remaining liver at sacrifice showed secure sealing of all biliary and vascular structures in the LigaSure groups. Not unexpectedly, thermal injury from standard electrocautery was 4 times greater than that observed in tissue examined where the LigaSure device was used, as measured on histological specimens.

One animal in Group I had a bile leak detected on HIDA scan. However, this leak was not discernible upon subsequent visual inspection and was considered clinically insignificant. No biliary leaks occurred in the LigaSure groups identified by HIDA or visual inspection. Additionally, postoperative bleeding was absent in all animals as confirmed by gross inspection on postoperative Day 2.

Table 1.
Intraoperative Blood Loss and Operative Times

	Group I	Group II	Group III
Operative Time	65 ± 5 minutes	40 minutes*	22 ± 2 minutes†
Blood Loss	200 ± 5 mL	<20 mL†	<20 mL†

*$P<0.01$.
†$P<0.001$ vs Group I.

DISCUSSION

Laparoscopic surgery provides benefits to the patients, such as shorter recovery time, less pain, and more cosmetically acceptable incisions. The surgeon may also benefit due to improved visualization of anatomic detail. However, solid visceral organs such as the liver pose a significant challenge to the laparoscopic surgeon because they have a soft parenchyma richly interspersed with vasculature.[14] Realization of the potential advantages of laparoscopic liver resection requires the technical ability to ensure hemostasis during division of the parenchyma. The effectiveness of laparoscopic instrumentation in maintaining a hemostatic, clear operative field has not been well documented to date. Due to this fact, the application of laparoscopic surgery to procedures on the liver has been delayed by the lack of appropriate instrumentation, and the testing of laparoscopic surgical techniques.

Greater acceptance of laparoscopic liver resection requires careful evaluation of the safety and efficiency of available technology and techniques. To date, laparoscopic liver resection has been evaluated in several case studies demonstrating the expected benefits to patients: decreased postoperative pain, reduced trauma to the abdominal wall, smaller incisions, shorter hospital stay, and earlier ambulation and return to normal activities compared with conventional liver surgery.[15–19]

In this study, we evaluated the application of vessel-sealing technology to liver resection in both open and laparoscopic approaches. Our findings demonstrate effective sealing of intrahepatic blood vessels and bile ducts without requiring isolation. Little to no blood loss occurred using the LigaSure device as compared with that with the standard finger-fracture method of partial hepatectomy. Our specimens did not contain any veins greater than 7 mm, and we believe that other methods, such as endovascular staplers, would be required for larger portal or hepatic vein branches.

A significant limitation of laparoscopic surgery, which has prevented application to liver resection, is the difficulty in controlling blood vessels. Laparoscopic suturing is difficult in the best circumstances; trying to control a bleeding hepatic vein using laparoscopic suturing would be a formidable undertaking. The ability of the LigaSure device to effectively seal intraparenchymal blood vessels is a significant advancement that increases the feasibility of laparoscopic liver resection. The additional finding that bile ducts were effectively sealed further strengthens the applicability of the device to liver resection.

The effectiveness of the LigaSure in nonanatomic liver resection in this study emphasizes the importance of new surgical technology in extending the range of laparoscopic procedures available to the surgeon. There is no question that liver resection, especially nonanatomic, is a technically challenging operation. The application of laparoscopic techniques to these procedures should be considered only where full support for advanced laparoscopic procedures is available, and by surgical teams experienced in all aspects of liver surgery.

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